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MANAGEMENT DECISION MAKING AND THE COMPUTER

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AND THE COMPUTER

by

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Lieutenant, Supply Corps

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
MANAGEMENT(DATA PROCESSING)

United States Naval Postgraduate School
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ABSTRACT

The place of the manager in the computer age is surveyed with respect to two specific parts of the economy--general industry and the federal government. The capabilities and potentialities of present-day computers as decision makers are compared with some of the early predictions of Turing and Wiener. A result of this analysis is a more realistic view of the computer's role in the management decisions of today and the future.

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CHAPTER I

INTRODUCTION

Can a machine really make decisions? More specifically, can a machine perform the work of a manager? Fifteen years ago, these questions would have been considered preposterous-yet in today's world of computers and automated techniques, they are perfectly relevant. Each day a new use is discovered for computers or other mechanized devices in tasks which human beings previously performed. The substitution invariably seems to result in improved efficiency and accuracy, and, typically, the comparisons made favor the machines over the human who was supplanted.

The past fifteen years has also witnessed a proliferation of literature on the subject of management in general. Several colleges and universities have instituted separate Management curricula. Management consultants have an established place in the business community. Executives are encouraged to attend management seminars. Scores of magazines devote themselves to the subject of management exclusively, and many more treat the subject from functional levels, e.g., Shop Management, Plant Management, etc. In short, the past 15 years has highlighted the confluence of two advances--management techniques and computer technology.

This thesis examines the effect of these two advances with regard to the place of the manager in a computer-oriented society. In particular, the manager in industry and the military or governmental manager are examined. These two groups have been singled out for several reasons.

First, each is reasonably homogeneous with respect to individual goals. The manager in government has as his ultimate objective what Dr. Hitch, Assistant Secretary of Defense, Comptroller, calls the "optimal" mix of elements which will produce objectives stated by the electorate.[1] Industry's ultimate objective is, of course, profit. Incidentally, it will be noted that these two goals are quite similar.

Secondly, these groups make up a significant percentage of the American business population.

Thirdly, Industry and Government have been the leaders in the prosecution of the changes in management techniques and computer technology and thus better represent these changes than other fields like Medicine and Education.

This thesis investigates concurrently the nature of the business or industrial decision in its most current sense. It focuses its attention almost exclusively on the decisions which machines are now permitted to make within industry and the federal government. The objective of this investigation is to summarize, insofar as is possible, the applications of machines to human decision making at present and, to extrapolate, what may reasonably be expected in the future.

Chapter II presents a background of some of the early theories which influenced the attitudes toward mechanization

[1] Hitch, C.J. and McKean, R.N. The Economics of Defense in the Nuclear Age. Harvard University Press, 1961: 109.

of the decision making process. In particular, the pivotal analysis of A. M. Turing is discussed. This background discussion draws a rough analogy between the brain and a typical computer in an effort to put the subsequent analysis in the proper perspective. Several of the recent developments in the use of machines for quasi-human functions are also mentioned.

In Chapter III a definition of the decision process is established, followed by a definition of a decision. These definitions are useful in several of the comparisons which follow.

Chapter IV examines many of the representative types of decisions which are made by the computer in industry. The popular "management by exception" technique as it affects management is discussed. Industrial Dynamics is introduced as a promising device which may eventually give great precision to some business decisions which are now made by less exact methods. The Total Management System in theory and in one working example in a large corporation are then described. Finally, the traits which distinguish successful computer management from marginal management are analyzed in the light of a recent survey.

Chapter V describes the use of computers in the Federal Government, including the largest user, the Department of Defense. In particular, the quantitative analysis current in the Department of Defense is described, due to its susceptibility to computer applications. Several analogies between

industrial and DOD systems are noted, the most significant being the chemical process control's similarity to the SAGE System. Several unusual applications of computer techniques are also discussed.

Chapter VI introduces examples of some non-doctrinaire views on computer applications. Most of these are the results of an industry questionnaire which produced some very frank and penetrating observations.

Chapter VII synthesizes the ideas presented in the previous sections.

Finally, Chapter VIII draws conclusions concerning the material presented. The author hopes that the analysis provided by this thesis will help to clarify the position of the manager in both industry and the federal government.

CHAPTER II

BACKGROUND

Thinking

In order to understand the nature of decision making in the machine sense, or even the human sense, it must be clearly understood that the word, "thinking", has connotations not at all appropriate for joint use. Below will be enumerated several of the tasks which machines can now perform:

1) Play an outstanding game of checkers[1]
2) Play a moderate game of chess.[2]
3) Compose music.[3]
4) Operate an entire closed-loop petroleum cracking plant.[4]
5) Perform an adequate, though by no means perfect, translation from Russian to English, and vice versa.[5]
6) Prove Trigonometric Identities.[6]

[1] Gruenberger, M., editor. Management and the Computer of the Future. MIT Press, 1962: 23.

[2] Shannon, C. E. A Chess Playing Machine. The World of Mathematics. James R. Newman, editor. Simon and Schuster, Vol. 4.

[3] Hiller, L. A. and Isaacson, L. M. Experimental Music. McGraw-Hill, 1959.

[4] Anonymous. Computer Controls a Big Cracker. Oil and Gas Journal. December 5, 1960: 73.

[5] Alt, Franz. The Outlook for Machine Translation. Advances in Computers, vol. 3: 203.

[6] Gruenberger, op. cit.: 102.

7) Design motors.[7]

8) Operate the entire billing and updating function in an insurance company.[8]

9) Maintain Inventory Control records for over 1,000,000 items.[9]

This list is by no means all-encompassing, nor is it meant to be anything more than a sketch of some of the things which a machine, particularly a digital computer, can now do. These tasks will be recognized as ones which are usually associated with the thought process of human beings.

It is difficult to arrive at a common denominator for assessing the similarity of machine processes to the human's decision processes. Several early papers attempted to deal with this question, either directly or by allusion. The most influential from the point of view of degree of impact are those of Turing, Von Neumann, and Wiener. Several contemporary writers have advanced newer versions, but their analyses generally reduce to variants of the early authors just mentioned. Today, the tangible achievements of Simon and Forrester have come closest to actual design fruition of what might be called a machine which of itself decides.

[7] Goodwin, G. L. Digital Computers tap out designs for large motors....fast. Power. April, 1958: 12.

[8] Blumberg, D. F. Computer Applications for Industry and the Military-A Critical Review of the Last Ten Years. Proceedings-Spring Joint Computer Conference, 1963: 185.

[9] Author's knowledge of the Department of Defense supply systems.

Contributions of Turing

Even in the late thirties, A. M. Turing foresaw the capacity of machines, yet to be invented, to perform human inductive and deductive tasks. It remained for him to write, in 1950, an article which was to crystallize the opinions of many concerning this issue. His article, "Can a Machine Think?", offers a very straightforward approach. He first dismissed the use of the word "think" as being absurd since it is entirely human in its connotation. As a substitute for a definition of "thinking", he introduced a test for determining a machine's ability to perform certain human feats.[10] In his test, or "imitation game", three people--a man, A; a woman, B; and an interrogator, C, who may be of either sex, are placed in separate cubicles. The object of the game is for the interrogator to determine which of the other two is the man and which is the woman. The interrogator is permitted any number of questions. He may ask them of either A or B. Player B is an accomplice of the interrogator. She will do her best to make it possible for the interrogator to distinguish her sex. Of course, the man would try to give as many confusing answers as possible to make his sex not at all obvious. He would state his weight at 103 pounds, for instance, and, when asked what his interests were, might reply, "housekeeping", or "taking care of the children". Also, a suitable intermediary, like a typewriter, could be used to obviate the voice bias and make

[10] Turing, A. M., James R. Newman. op. cit.; 2099.

the game more completely objective. The crux of Turing's imitation game is the effect of a machine taking the part of A. His method of determining the "humanness" of the machine is to contrast the machine's ability to deceive the interrogator as compared with the human's ability. The machine would be programmed to be as confusing as programming technology would permit. The number of situations which a machine would cope with would also be a function of the technology of the day. Turing asserted that he believed that within fifty years' time the average interrogator will not have more than a seventy percent chance of making the right identification after five minutes of questioning.[11]

What makes Turing's test so important is that it facilitates the difficult task of judging whether a machine or system of machines can have similarities to the human thought process. Many of the objections to the concept of a machine-oriented thought process are rather abstract and metaphysical in nature. By Turing's game, a strictly behaviouristic test is adopted and the arguments of the "negativists", whom Turing describes as those having opinions "contrary to my own", are diverted, if not altogether resolved. Turing offered rebuttals to the views of these negativists. Some will be commented upon, since even now, 14 years after his paper, they continue to appear in varying degrees of intensity. Some of these diverse arguments

[11] Ibid., 2100.

are the following:

<u>The theological objection</u>. This is probably one of the first which comes to mind. Those who hold this view argue that thinking is a function which comes from the depths of man's immortal soul. It cannot, therefore, be performed by something inanimate which has not been endowed with a soul.

<u>The "heads in the sand" objection</u>. The author knows some people who are repelled simply by the thought that machines can duplicate some complicated human thought processes. This objection is rather specious, but nonetheless prevalent.

<u>The mathematical objection</u>. Probably the strongest rallying point of this school is Godel's Undecidability Theorem. Although Godel certainly did not anticipate the use of his theorem in the context here described,[12] many have found it to be the means of refuting the possibility that machines can think. Godel's theorem shows that in any logical system, statements can be formulated which can neither be proved nor disproved within the system, unless possibly the system itself is inconsistent.[13] The relevance of this theorem to the limitations of the computer is questionable, however.

<u>The argument from consciousness</u>. This one is probably

[12] Taube, M. Computers and Common Sense. Columbia University Press, 1961: 14.

[13] Turing, Newman, <u>op. cit.</u>: 2109.

the best known and can be expressed by a quotation from Professor Jefferson's Lister Cration for 1949;

> not until a machine can write a sonnet or compose a concerto because of thought or emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain--that is, not only write it but know that it had written it. No mechanism could feel (and not merely artificially signal, an easy contrivance) pleasure at its successes, grief when its valves fuse, be warmed by flattery, be made miserable by its mistakes, be charmed by sex, be angry or depressed when it cannot get what it wants. [14]

In short, this group requires that a machine be able to "feel" or be conscious of the sentiments described, whether this consciousness contributes to the attainment of an objective or not.

<u>Arguments on various disabilities</u>.[15] These are based on the fact that there are many things which machines cannot do, like enjoying strawberries and cream, having the ability to make one fall in love with them, learn from experience, and the like. In substance this argument holds that until **machines** can be programmed to perform Feat X they cannot duplicate the human thought process. As a practical corollary, once the machine is finally programmed to perform Feat X, the comment is often made, "So what--this machine cannot perform Feat Y now," and so on. Some would argue, as Turing does, that to say a machine cannot do this merely means that not enough capacity has yet been built into a machine. By capacity in this sense is meant

[14] Ibid.: 2110.

[15] Ibid.: 2110.

the net ability of a machine to have access to and operate on information in various forms. This capacity is primarily a function of the machine's logical design and storage devices, e. g., disk, drum, capsule, etc. In other words, one counter argument is that the only limit for the resources or resourcefulness of the computer is the amount of information which it can have available in its "brain".

"Machines don't originate anything".[16] This argument is based on the fact that all machines must be programmed to perform the task which they are given. Therefore, they are incapable of the human-like reflexes which are called, under varying situations, intuition, industry, judgment, and others. One rebuttal to this might be that the human being is, in a sense, "programmed" from his very earliest days and the intellectual achievements which characterize his conduct are the results of this work by the Master Programmer.

Cybernetics

While the comments of Dr. Turing are fundamental in their perception of future thought in this field, the work of the late Dr. Norbert Wiener of MIT has resulted in more specific, tangible applications. In 1948, Dr. Wiener published his Cybernetics, or Control and Communication in the Animal and the Machine. In this short book he described his view that only through a synthesis of the vocabulary and the modus operandi of many disciplines would it be

[16] Ibid.: 2111.

possible to arrive at a common ground for analyzing the interaction of humans and machines.[17] Through Cybernetics he hoped to reduce many works that seemed peculiar to neurophysiology, for instance, to applications in other fields, like electricity or physics. Much of this new science was based on the idea of feedback. This feedback concept has analogies throughout the physical and social sciences. The action of a thermostat, the motion of a person reaching for a pencil, the firing of an anti-aircraft gun, all have as a common element a continual re-alignment of a desired goal, such re-alignment taking place within finite time intervals.

In particular, Dr. Wiener saw application of Cybernetics in the fields of neurophysiology and prosthesis.[18] Many of his colleagues hoped that his ideas be extended into other fields. To this, Wiener strenuously objected. At any rate, a very substantial coterie of scientists, mathematicians, and people in other fields have found Cybernetics to be an apt way of expressing concepts common to their disciplines.

As a supplement to Wiener's work on feedback in human systems, several persons have suggested methods of analyzing electrically, chemically, or even mechanically, the operation of the human brain in order to compare it with high-speed digital computers. It is, in fact, possible and instructive to draw a very rough comparison between the capacity of a human being and some selected characteristics of

[17] Wiener, N. L. Cybernetics. John Wiley and Sons, Inc., 1948: 169.

[18] Ibid.: 169.

a digital computer. Von Neumann's "The Computer and the Brain" formulates a useful framework for developing such a comparison.[19] Table I represents characteristics of the human brain in language of neurophysiology.[20] Table II represents a group of computer characteristics in the language of an electrical engineer.[21] Table III compares the computer with the brain by reducing words common to the physiologist and engineer to words which the layman can understand.[22] Needless to say, the analogy is not complete. The computer has no analog for several processes which occur in the brain. There are many other assumptions, especially those involving the pulse rates and degrees of retention of material in the human memory, which have not as yet been proved and which would affect the comparisons substantially. One trait which stands out in this analysis is the fact that the human brain is far more compact in its arrangement. On the other hand, the machine has a great speed advantage over the human. While no standards of accuracy are enumerated here, the very diversity of the chemical, electrical, and mechanical processes which go on in our brains suggests a greater possibility of error.

[19] Von Neumann, J. The Computer and the Brain. Yale University Press, 1958.

[20] <u>Ibid</u>.: 44-49.

[21] <u>Ibid</u>.: 47-49.

[22] While most of the basic data is based on Von Neumann's work, the "bridge words" and some of the obvious numerical changes are the author's.

TABLE I

Human Brain Characteristics

Trans-Synoptic Stimulation and Fatigue Time	10^{-2} sec.
Size of Membrane	10^{-5} cc.
Volume of Brain	10^{3} cc.
Number of Neurons in Brain	10^{10}
Volume-per-Neuron	$\frac{10^{3}}{10^{10}} \cong 10^{-7}$
Dissipation per Cell (Neuron)	10^{-9} watts
Memory Capacity by Age 60	10^{20} bits

Reference: Von Neumann, J. The Computer and the Brain. Yale University Press, 1958: 44-49.

TABLE II

Medium Computer Characteristics

Reaction Time	10^{-6} sec.
Inter-Electrode Distance Transistors	10^{-2} cm.
Volume	10^{6} cc.
Core Storage Capacity	3×10^{4} cells
Volume-to-Cell Ratio	$\frac{10^{6}}{3 \times 10^{4}} \cong .33 \times 10^{2}$
Dissipation per Cell	10^{-1} watts
Total Storage Capacity (with modular devices)	10^{9} computer words

Reference: Von Neumann, op. cit.: 47-49, combined with data representative of a medium-fast computer, e. g., CDC 1604.

TABLE III

Comparison of Brain with Computer

Brain		Computer
10^{-2} sec.	Time required to act on an input command	10^{-6} sec.
10^{-5} cc.	Size of Action Surface	10^{-2} cc.
10^{3} cc.	Volume of Computing Medium	10^{6} cc.
10^{10} cells	Self-contained Storage Capacity of Conducting Medium	3×10^{4} cells
$\frac{10^{3}}{10^{10}} = 10^{-7}$	Volume to Storage Unit Ratio	$\frac{10^{6}}{3 \times 10^{4}} \doteq .33 \times 10^{2}$
10^{-9} watts	Dissipation per self-contained Storage Capacity	10^{-1} watts
10^{20} bits	Maximum Total Usable Storage Capacity	10^{10} bits

General Problem Solver and Heuristics

In the mid-fifties, Drs. Simon and Newell began their work on a programmed machine which would diminish the difference between human achievement and the feats possible through careful programming. They designed the General Problem Solver, which has the capacity of proving many difficult theorems.[23] It is able to explore many avenues which a human being would take with great expenditure of time and fatigue and discover the one which most effectively solved the problem.

This process is rendered still more streamlined by the introduction of heuristic programming. This modification to what might be called a brute force method of searching all possible alternatives, tries to use rules of thumb which might take a very educated guess at the best avenue, rather than trying them all.[24] While this is not an exact method, it does cut down significantly on machine time. The type of problem and the variety of problems which the GPS is capable of solving have become more and more diverse. Goals rather than problems are the essence of the GPS, but its most common use is to set as a goal the solution of what is typically referred to as a problem, like proving a trigonometric identity.

[23] Simon, A. and Newell, A. Computer Simulation of Human Thinking and Problem Solving. Datamation, July 1961: 35.

[24] Tonge, F. The Use of Heuristic Programming in Management Science. Management Science, April, 1961: 231.

Simon and his associates, as well as many others, have also experimented with the "learning machine". This machine can be programmed to make proper allowances for errors discovered. By this is meant that if a particular course of action leads to an undesirable result, the machine senses this and does not apply that course of action in future operations. Typical of this latter development is the machine which can be programmed to play chess and checkers. Especially in chess, where the number of possible moves is astronomical, it becomes necessary to limit the type of move to those which have proved in the past to be more worthwhile than others.[25] This, combined with the heuristic programming mentioned earlier, reduces significantly the amount of searching a machine must do to discover the correct next move. Even so, several hours of machine time are required in even the most simple chess-playing program, and this program still will lose to a reasonably good player.[26] It could here be argued again that the only barrier is capacity. Many other specialized applications of learning machines are being worked on. Solomonoff developed what he calls an Inductive Inference Machine which approximates the conduct of a human faced with a series of alternatives, some of which have already been faced before. His machine in particular may someday find use in information retrieval,

[25] Shannon, Newman. op. cit.: 2127.

[26] Ibid.: 2127.

where cataloguing, an essentially human endeavor, poses the most serious problem.[27]

Outlook

The development which most closely parallels real-world applications is Dr. Forrester's Industrial Dynamics. By utilizing the idea of feedback as applied to a business enterprise, Dr. Forrester has developed a program which can produce projections of a business cycle and a great variety of decision parameters.[28] Industrial Dynamics will be discussed in greater detail in Chapter IV. This dynamic feature of the feedback idea seems to hold great promise in the business world. It is still in its embryonic state, however.

The material just presented gives a very brief idea of the framework which has developed over the past 15 years for comparing the machine and the human. It is apparent that most of these methods are either still theoretical or just on the verge of being given some practical use. Another point which seems obvious is the practically supreme importance of good programs. The result of poor or marginal programming in a human and in a machine is a product which does not live up to the capabilities of the inventor. Parenthetically, it might be mentioned here that Dr. Wiener was very skeptical of the breakthroughs which seem so near in the

[27] Solomonoff, R. An Inductive Inference Machine. 1957 IRE National Convention Record, Part 2: 56.

[28] Forrester, J. Industrial Dynamics. MIT Press, 1961: 13.

fields mentioned. He foresaw the day when the ability of man to control the machines which he has devised may be lost.[29] This is typical of the many contrasts which one discovers in the writings of this field. On one hand there is nothing but the most complete optimism for machines, improving and working in the most symbiotic[30] way with their designers. Yet, on the other hand, some like Wiener and Taube[31] predict dire consequences as the result of the mechanization of so many human processes. Wiener's gloomy attitude toward this problem was based on the spectre of a computerized war machine. Several papers have been presented recently which view the danger as coming from a sociological decay, occasioned by an inexorable trend toward computerization of all things. Their remedy, incidentally, is not to decrease the emphasis on machine uses, but to increase the emphasis on education and "ethical concepts".[32] With all this in mind, the analysis of a decision can be considered in the proper perspective.

[29] Wiener, N. <u>op. cit.</u>: 188.

[30] 'Symbiotic' and the noun 'symbiosis' define the situation where two dissimilar organisms (in this case human and computer) have an intimate association which benefits both to some degree.

[31] Taube. <u>op. cit.</u>: 95.

[32] Brome, V. The Problem of Progress. Cassell, 1963: 222.

CHAPTER III

DECISIONS

Since this paper deals with decision making, it will be necessary to select a definition for the word "decision". Practically every writer in the field of management has determined his own description for decisions, or the decision making process. A few representative definitions are the following:

> a conscious choice or selection from a group of two or more behavior alternatives.[1]

> the choice of alternatives based on judgment.[2]

> the selection of one behavior alternative from among two or more possible alternatives.[3]

> a decision is the formation of an opinion or a conclusion, a determination of a controversy, or the making of a choice between possible courses of action or between persons.[4]

> decision grows out of a choice of one course of action from alternative courses.[5]

[1] Tannenbaum, R. Managerial Decision Making. Journal of Business, Vol. XXIII, January, 1950: 23.

[2] Glover, J. G. Business Operational Research and Reports. American Book Co., 1949: 12.

[3] Terry, G. R. Principles of Management. Richard D. Irwin, Inc., 1953: 106.

[4] Owens, R. N. Introduction to Business Policy. Richard D. Irwin, Inc., 1954: 115.

[5] Jamison, C. Business Policy. Prentice Hall, Inc., 1953: 120.

None of the above descriptions is particularly astonishing, and increased precision in the definition is of little importance. The idea which these definitions, and common sense, yield is that the essence of a decision is picking among possibilities or alternatives.

Suffice to conclude with the general view that decision making is a three-step process. The first step involves the assessment of the problem; that is, determining that the moment has arrived for a decision to be made.

The second step involves a listing of all the alternatives. Since there are normally many ways of accomplishing a desired result, this step in essence catalogs all the possibilities and, if necessary, weights them either empirically or by intuition in preparation for the third step.

Step three in this synthesized definition of the decision making process is deciding among the alternatives developed in step two.

Using the definition that <u>a decision involves choice from among a group of alternatives</u>, two kinds of decisions suggest themselves. Simon refers to them as programmed and non-programmed decisions.[6] Another name might be "automatic" or "routine" decisions, and "hunch" or intuitional decisions. Examples of simple programmed decisions are reorder points in a stock control system and computing pay in a large

[6] Simon, H. The New Science of Management Decision. Harper and Row, 1960: 5.

company. More difficult programmed decisions where the rules are more complicated but nonetheless defined would be process control systems, and some automated assembly lines.

In the non-programmed area, such decisions as when or where to buy a house, how to merchandise a special product or, in the military connotation, how and when to attack the enemy, are examples. Appendix II describes in greater detail the hierarchies of the programmed and non-programmed decision making techniques.

It has been necessary to examine the history of formal investigation in the field of man-machine interaction to give the proper perspective to what is now occuring. Further, a definition of "decision" needed to be extracted from the countless ones which proliferate in management texts and articles. These two things having been done, the investigation of industrial and government decision making may proceed.

CHAPTER IV

Decision Making in Industry

Applications

Practically all business enterprises have been automated in some way. Nearly every field of endeavor has changed its methods in order to keep pace with the increasing complexity and pressure of the business world. In particular, many of these concerns have gone beyond the stage of Gantt charts, log-log graphs, or other manual methods of picturing the business activity, and have actually installed unit-record equipment to speed up as well as to portray in meaningful terms various parts of the company's routine. Still others, and this group is increasing daily, have actually purchased computers. Over 16,000 computer installations exist in industry today.[1] A recent survey quotes some interesting facts about the companies that have computers. First of all, about three quarters of the companies in Fortune's Top Five Hundred listing <u>have</u> installed computers.[2] Some, like G. E., have installed hundreds while others are just buying their first ones. Secondly, the trend in computer purchases appears to be increasing, but at no predictable rate. The year 1961 showed the greatest number of companies embarking on a new computer program, and yet the years 1960 and 1962

[1] Industrial Securities Committee, A Survey and Study of the Computer Field. Computers and Automation, January, 1963: 15.

[2] Bock, R. et al. A Survey of Computer Use in Large Companies. Data Processing for Management. October, 1963:15

were well below the average of 1956 through 1959.[3] Nearly all the firms reporting were using their computers for payroll. Among the other applications, cost standards and records, work and process inventory, finished goods inventory, production planning, raw materials ordering, and parts ordering all showed various degrees of automation. The latter, incidentally, showed least computerization. Another comment on this report was that the number of different applications found since installation of computers had increased about threefold.[4] The final sentence of the report was, "There was no evidence that any firm was anywhere near complete computerization."[5]

How is the computer used in industry? In the financial community, computers are used in such applications as payroll, margin and cash accounting, customer statements, trade confirmations, commissions, dividends, and the production of a host of allied management reports. Computers are also used to speed up such routine work as calculating portfolio market values and yields, making records of company earnings, dividends and profit margins. A number of firms are experimenting with these machines for security analysis work.[6]

[3] Ibid.: 16.

[4] Ibid.: 18.

[5] Ibid.

[6] Industrial Securities Committee, A Survey and Study of the Computer Field. Computers and Automation, January, 1963.

There is a limitation in the ability of a computer to recommend a sale or purchase of stock, but current applications should improve the overall quality of investment decisions. The Midwest Stock Exchange is developing an electronic centralized bookkeeping service which will reduce back office expenses by more than 70% per order and will save member firms an estimated three million dollars a year in labor and machines.[7] Many other innovations are currently being planned or already installed.[8] One writer noted that even with all the uncertainties of adapting computers in business, the payoff is usually "quick".[9]

Computers are finding increasing use in process control applications, especially in the power and chemical industries, where the functions of major units, be they a cracking plant or a steam generator, can be reduced to a series of quantifiable parameters. Complexes formerly manned by humans are being replaced by highly efficient computer-directed units. This computerized unit is typically bothered only occasionally by a breakdown, and not at all by fatigue, and also is perfectly willing to accept any instructions given it. Sales of digital computers for

[7] Ibid.: 22.

[8] EDP Weekly. April 27, 1964: 9.

[9] Strickland, H. The Computer a Tool for Clerical Automation. Computers and Automation. April, 1963: 26.

process control are increasing at a rate of about 50% a year in the power and chemical industries. The power generating field alone has 200 systems on order.[10]

In 1956, Texaco announced that its Port Arthur, Texas, cracking unit was operating at a capacity of four million dollars, 1800 barrels a day, and was an entirely closed-loop process, being the first such fully automatic computer control industrial process.[11,12]

A year later B. F. Goodrich's chemical company's vinyl plastic plant at Calvert, Kentucky, became the first chemical plant to be entirely controlled by computers. Only a few days later Monsanto Chemicals began operating an ammonia plant in Luling, La., using a full on-line computer control concept.[13] This closed-loop or complete control, which is a feature of a process control system, means essentially that all information and measurements regarding the process are fed into the computer, which compares and calculates the data and then makes any necessary changes in the control setting. It does this by changing the set points on the recorder controllers, which operate like a thermostat on a home heating installation. When these controllers are set,

[10] Industrial Securities Committee. loc. cit.

[11] The Christian Science Monitor. September 3, 1959: Industry Finance Section.

[12] Anonymous. When Computers Take Over. Business Week, January 16, 1960: 28.

[13] Ibid.

the plant is able to run at its maximum output, and this maximum is constantly recomputed so as to cause a perpetual reevaluation of the efficiency of the system.[14] As can be imagined, a small increase in efficiency of large plants like the chemical or petro-chemical industries can easily offset the several hundred thousand dollars costs that such computer installations require. It should be emphasized that these plants will in effect run themselves without human intervention. An operating engineer and crew are on duty for maintenance and for takeover in case of emergency. However, the strength of the system and its essential operations are performed by signals and computations controlled by machines.[15]

Manufacturing companies are using computers for off-line production control in such applications as shop scheduling, assembly line balancing, scheduling labor utilization, and numerically controlling machine tools.[16] The field of Operations Research has been advanced as a likely catalyst to increase utilization of computer applications for these processes. By selecting an optimum combination of schedules, through some technique of mathematical programming more efficiency can be achieved in a particular production control

[14] Boehm, G. A. Next, a Solid State Vice President. Fortune, December, 1960: 237.

[15] Anonymous. Computer Controls a Big Cracker. Oil and Gas Journal. December 5, 1960: 73.

[16] Industrial Securities Committee. op. cit.: 22.

process, or so it is hoped. In retailing, the computer is especially useful in the inventory control area.[17] The decisions as to whether a product is available for transfer to a distant retailing activity can be programmed into the inventory control operation. The Westinghouse meter plant in Newark, New Jersey, is reported to be saving one million dollars a year through computer inventory control. Using sales figures, and taking into account the cost of labor turnover, machine set-up, etc., the computer decides when to stock an item formerly produced to order, and when to adjust inventory of an item losing popularity. Macy's in New York City, Dey Brothers in Syracuse, New York, and McCurdy's in Rochester, New York, are now reporting all fast or slow moving items in their daily computer-generated sales reports.[18]

In addition to the types of industrial decisions enumerated above which computers can effectively accomplish or support, there are thousands more. However, many have points of similarity with respect to the types of tasks accomplished. It has been estimated that the following tasks make up the bulk of man hour costs in industry.

1. Payroll
2. Billing
3. Supply[19]

[17] Smith, O. Automating Management's Current Confusion. Administrative Management, October, 1961: 20.

[18] Ibid.

[19] Industrial College of the Armed Forces, op. cit.: 34.

These tasks are clearly highly adaptable to a computer-oriented system. Their very repetitiveness and susceptibility to codification make them ideal for computer applications. Even so, in many large operations, the lack of sufficient capacity has been a significant barrier. For instance, if there are two million items of stock to be controlled by a random access process and each item required approximately 400 computer words, the upper limits of even the most advanced memory devices are exceeded.[20] Special circuitry or more sophisticated storage devices will solve this problem, but boundaries, determined by technology of the day, do exist. The advent of modular devices and better optical scanners, together with communication equipment advances, all point to even more computer based retailing decisions in the future.

Management by Exception

The preceding specific applications suggest that management by exception is becoming more possible in industry. This time-honored idea, set forth by Frederick W. Taylor in his book, "Scientific Management",[21] seeks to replace the manager, now literally swamped with reports, interim summaries, and a deluge of other detailed information by the executive who has only a condensed, summarized, and invari-

[20] Datamation. December, 1963. This issue describes an entire spectrum of upper and lower limits. See especially: 34.

[21] Taylor, F. W. Scientific Management. Harper Brothers, 1947.

ably comparative report. These comparisons would show deviations from standards, rather than actual quantitative amounts.

The only thing that makes possible the management by exception technique is a set of decision rules. At what point does an item become slow moving, or susceptible to special management? At what stock-turnover ratio should the district manager decide to execute Plan Z with regard to stock management? These are typical questions which must be answered in the program which the machine follows, if a management by exception rule is to be of any value. In fact, the trend today is to quantify nearly all decision rules if possible. Many weighty business situations have been reduced to algebraic or differential equations and programmed on the computer.

Industrial Dynamics

A further refinement of management techniques is expected through the new study of Industrial Dynamics. "Industrial Dynamics" is a name coined by Forrester and first given prominence in an article in the Harvard Business Review in 1958.[22] He defines his system in the following steps:

1) The available intuition, judgment and experience about the firm's operations are drawn together.

2) These estimates and guesses are formulated mathematically into a single coherent system--or model. Such a

[22] Forrester, J. The New Science of Industrial Dynamics. The Harvard Business Review, July-August, 1958: 37-66.

formulation can be sufficiently comprehensive to include all the possible considerations that seem important.

3) The behavior of this system is then studied through a digital computer by simulation methods.

4) The consequences of errors in the initial guesses can be determined and corrections made.

5) At this point analysts are in a position to determine which factors and relationships are critical in the company operations and which are unimportant. For example, the choice of advertising medium might not have so much impact on the company as the timing of promotion campaigns. After the critical factors have been identified, field measurements can be devised to secure the necessary data. This sequential approach conserves effort in the expensive field phase of the program.

6) This series of steps is repeated on a continuing basis to refine the analysis and to introduce newly discovered factors.[23]

At the risk of abridging beyond recognition the stand of the industrial dynamics school, it is their contention that enough segments of the industrial cycle are reducible to finite numerical terms so that the precise interactions of one segment or node with another can be reasonable typified through a model. Having once developed this model and tested it through simulation, it is possible to reduce

[23] Forrester, J. Industrial Dynamics, op. cit.: 44.

many real-world decisions to a series of relationships which in turn can produce a series of graphs. These graphs can give a definitive answer to the manager with regard to many of the alternatives which he faces. This is certainly a promising approach to the solution of non-programmed problems. Appendix I shows a typical result in an Industrial Dynamics problem where only a few of the variables considered are plotted. A manager, who would certainly understand the relationship of the variables and be guided by the implications of the graph, is able to determine his course of action either by the direction given through the computer program or by an analysis of the numerical tableau presented.

Total Management Systems

Another approach published in 1963 by Dr. R. L. Martino proposes a total management system.[24] This system, once again, is dependent upon the ability of a simulator to aid in the construction of the model. Once the model is constructed, it is constantly updated by the feedback put into the system. An example of Martino's approach is to be found in Appendix III. Martino admits that the task of constructing this sort of total management system is not an easy one and requires complete dedication on the part of line

[24] Martino, R. A Total Management System. Datamation, April 1963: 32.

personnel, particularly.[25]

Of course, the systems analyst must have an important place in the implementation of this concept, since he will be doing the theoretical and practical computation which will be the basis of the computer program. He, then, must also be deeply conversant with the operating characteristics of the system. Once again, the success of this method depends upon a great deal of quantifiable information concerning the industrial cycle.

One company has already put in use a total management system similar to that proposed by Dr. Martino. Westinghouse Electric Company has established a central tele-computer center with connections to all their large divisions throughout the United States.[26] This center has two UNIVAC 490 central processors, random access memory devices capable of storing over seventy million characters and twelve tape units. In addition, there is a switching keyboard to distinguish the tasks for the computer room and those for the communications center.[27]

The Westinghouse system operates on a real-time basis, and is designed to gather data, prepare reports, transmit and receive messages, perform stock distribution, process

[25] Ibid.: 37.

[26] Cheek, R. Management Communications Unlimited. Input (Univac publication), April, 1964: 5.

[27] Ibid.

orders, record historic data and a great variety of other management tasks. The salient feature of this system is that it is a "clearing house" for nearly all of the factors which management considers in the decision process. Westinghouse reports savings in many areas. A typical example is that through increased availability of information on billing, cash flow has been increased by five days.[28]

Significantly, the company is already planning to refine this system even further by having visual display units at the central office in Pittsburgh. These units would be able to provide top management with a required statistic, literally at the pressing of a button.[29]

From the information above it can be seen that the computer oriented management decision is being given consideration and has found practical use in industry. All the situations cited fitted roughly into the "programmed" type of decision. Especially in the area of amassing great quantities of information and then following some specific programmed instructions concerning the information, the computer is seen to have a preeminent place in management science.

With regard to the definition of a decision adopted earlier, the applications already cited show that a computer is capable of dealing with many types of decision problems encountered in industry. In many cases the problems are

[28] Ibid.: 7.

[29] Ibid.: 18.

simple, as in payroll and billing. In other cases, like process control, there are a great many more rules which must be entered into the program before the computer knows how to react to the finite number of situations to which it may be subjected.

In addition, the computer has proved itself capable of presenting an almost limitless spectrum of output results in any desired form. Whether printing checks, accounts receivable, or showing market fluctuations, the ability of a computer to solve such problems and present the results in a rapid, efficient manner is unchallenged.

From this one might conclude that the computer can make all business decisions. All the evidence presented suggests that the decisions which can be reduced to a routine or a finite set of alternatives can be solved directly by computer within time frames which humble even the most masterful clerk or foreman's effort in people-oriented systems. Yet it should be reemphasized that these decisions fall roughly within the definition of Simon's programmed decisions. The intuitional or possibly strategic decision, typically without many of the quantified alternatives does not fit the pattern of decisions described as already computerized in industry. The Murchison Brothers do have many computer-developed alternatives available to them when they make a decision, but the real basis for the countless profitable decisions they make (and the non-profitable ones, too, although these seem to be rare) is not the computer alone. It is a combination

of the information which _is_ available with that which must be surmised, divined, or predicted. These are the non-programmed decisions. The typical manager is faced with many of them each day and seldom requires solely a machine's help to make his decision, although the aid provided by the computer is substantial.

Levels of Utilization

It will be remembered that ten years ago, very few companies even possessed unit record equipment, much less computers. The trend of the early fifties toward decentralization (which trend, incidentally, was fostered by many management texts and armchair managers) was voided by the ability of computers to handle and present great quantities of information to managers. So the trend to centralization recurred. Another significant trend involves the orientation of work.

The earliest efforts were directed at tasks. This in time yielded to the function and, finally, many processes now deal with projects.

A project cuts across various functions and acts as the focus of realistic managerial analysis.

The trend described above indicates that once we have learned to manage larger and larger projects we will learn to handle various projects concurrently and finally might possibly achieve orientation of the business as a whole. This last statement leads to what might be called the ultimate in managerial use of computers. Ambers' hierarchy

of Decision (Appendix IV) suggests that examples of the mechanization of some of these "ultimate" factors already exist.

Since it has been abundantly clear that computers can compute pay or determine high or low months for stock and perform other routine tasks, does it not seem likely that the next step in the hierarchy application is at the <u>tactical or implicit decision</u> level? Here computers might be programmed to determine which supplier to place an order on[30] or whether to manufacture the part in a plant, the typical make-or-buy decision. Some of this is already being accomplished by computers.

Also, there is the <u>planning</u> level. Decisions on sales forecasting, contract bidding, or project master scheduling are all aided by the use of computers. Possibly a subsequent step is having the machine <u>devise</u> the plan, too. Finally, there is the use of computers at the <u>strategic</u> level. This is the true non-programmed level. There have been several very worthy attempts in this area, Simon's General Problem Solver being one, and the study of industrial dynamics fostered by Professor Forrester also being very significant.

Typically, then, the computer's use in making decisions in industry currently is characterized by:

[30] The Navy's Aviation Supply Office has already computerized many segments of the purchasing function.

1) Diminishing the lower-level management decision load.

2) Reducing the number of clerical people to provide a given level of service.

3) Upgrading the kind of service given.

4) Managing much of the business on a structured, item-by-item basis.

There are substantial hopes founded on past experience and the existing technology that the non-programmed decisions of today may someday be routine.

The McKinsey Survey

Before leaving the subject of decision making by computer in industry, it would be appropriate to question the ability of industry to use the capacity of present-day computers to their utmost. The results of the McKinsey Survey[31] completed within the last year furnish some surprising information. The company sent a four-man team to study more than three hundred computer installations in 27 major manufacturing companies. These men took nearly a year over their study, interviewing top executives, operating managers, and computer specialists. The score: 18 companies out of 27 are not saving enough on computers to cover their investments.[32] McKinsey lays this at the feet of top management, suggesting that once management becomes deeply involved, pervasively involved, with the computer, the increasing benefits

[31] Gerrity. Getting the Most Out of Your Computer. Pamphlet published by McKinsey and Company, Inc., 1963.

[32] *Ibid.*: 10.

of its use can be obtained. What McKinsey discovered additionally was that, first of all, investment in computers can be justified by saving clerical costs alone.[33] These clerical costs are a function of the three processes mentioned earlier; payroll, billing, and supply. Such costs as Research and Development are not important from a standpoint of their effect on total corporate outlay.

All the companies that were operating well were paying for their systems through these savings, and, of course, everything else is clear profit. Secondly, the research group determined that most top executives really do not need the information generated by a computer as much as might be thought. In fact, daily or hourly reports sometimes distract rather than aid top management, the report concludes.[34] It does not seem unfair to speculate as to whether a management which is unaware of and rather profligate in the utilization of its computer potential might not someday be replaced by the tool which he apparently does not care to understand.

[33] Anonymous. Only One out of Three Pays for Itself. Business Week, April 13, 1963: 156.

[34] Ibid.

CHAPTER V

DECISION MAKING IN THE GOVERNMENT

Applications

The Federal Government is the largest single user of computers in the world.[1] By the end of this year, over 1500 will be in use in government applications, which compares significantly with over 16,000 total computers installed throughout the United States.[2] To assess the impact of the decision making done by the computers in the Federal Government, facts like 50,000 man-years used, or, over $630,000 operating costs,[3] do not give valid indicators of the situation. Many of these computers have highly specialized uses. Many, additionally, are being used for research and development work, where the management decision making applications are limited. (see Figure 1 for general utilization and cost data.)

It is seen that the Department of Defense has the greatest share of computers in the government, with over 1000. Among the individual Department of Defense services, the Air Force has 516, the Army 237, and the Navy 229 computers,

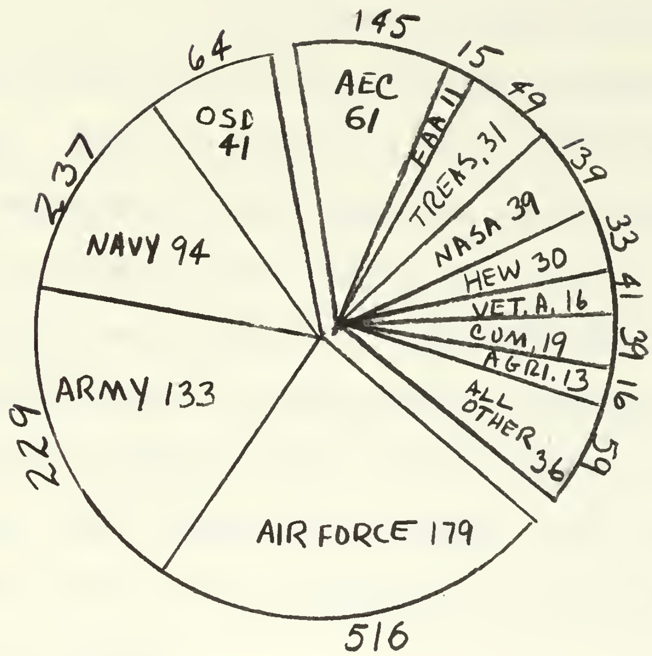
[1] Anonymous. New Tool, New World. Business Week. February 29, 1964: 80.

[2] Industrial Securities Committee. A Survey and Study of the Computer Field. Computers and Automation, January, 1963: 15.

[3] Bureau of the Budget. Inventory of Automatic Data Processing (ADP) Equipment in the Federal Government. Government Printing Office. October 25, 1963: 9. The quoted statistics, though representative of other fiscal years, are for FY 1963 only.

Figure 1.

FEDERAL GOVERNMENT USE OF COMPUTERS
FISCAL YEAR 1963



Key: Totals within circles represent millions of dollars in operating costs, Fiscal Year 1963. Numbers outside circle represent projected number of computers through Fiscal Year 1964.

Source: Inventory of ADP Equipment in the Federal Government, Bureau of the Budget Publication, Government Printing Office, 1963: 7.

based on projections through 1964.[4] It will be noted that the military's share dwarfs the amount allotted to the other agencies.

The Treasury Department has found computers invaluable for handling diverse tasks; e.g., check payment reconciliations with four hundred million checks annually, savings bonds, auditing, and many of the other tasks with which the department is involved.[5] The Atomic Energy Commission employs computers primarily for the research programs which it supervises. Many of the most recent advances for which AEC has been responsible have been due to the ability of the computer to simulate the atomic reactions which take place at miniscule time intervals.[6] In particular, the STRETCH, an extremely large and expensive IBM machine at Los Alamos, conducts mock weapons tests for the AEC and simulates H Bomb explosions. All these applications, while immensely important, do not bear on the purposes of this paper and will not be expanded further.

The Veterans' Administration is responsible for a life insurance program which is one of the world's largest. There are approximately 6.4 million policies in force. The annual

[4] Ibid.: 13.

[5] Comptroller General of the United States. Review of Automatic Data Processing Developments in the Federal Government, mimeographed, Dec., 1960: 26.

[6] U. S. House of Representatives. Hearing Before the Subcommittee on Census and Government Statistics of the Committee on Post Office and Civil Service, Part 3. U.S. Government Printing Office. 1963: 323.

incomes from premiums and other revenues is almost one billion dollars. Annual disbursements amount to almost $800 million. Invested funds aggregate seven billion dollars.[7] In particular, the VA's Department of Insurance conducts its mammoth record-keeping and accounting operation through its field stations by the use of computers. The master record file, which is the heart of the system, is operated by an entirely programmed set of decision rules.[8]

The Department of Commerce employs its computers for a variety of uses, but the best known one is the census. The census, like many of the processes described in other federal agencies, accepts information and, using a detailed program, performs calculations involving that information, in much the same way that inventory control is done.

NASA uses the majority of its computers for scientific work, simulation, and other research and development activities. Rather analogous to the AEC uses, the NASA computers' applications are particularly concerned with the development of new programs rather than decision criteria within the framework contemplated by this paper.

<u>Defense vs. Industry</u>

The Department of Defense's use of computers differs significantly from industry's. As mentioned in Chapter IV, the greatest uses of the computer in industry are payroll, billing, and supply, in that order. In government applica-

[7] Comptroller General of the United States. <u>op. cit.</u>:24.

[8] <u>Ibid</u>.

tion, this scale changes, with supply being the primary application of computers.[9] Since the supply system within the Federal Government, especially the Department of Defense, is so enormously complicated and requires such complex interactions of various functions, this percentage does not seem unreasonable.

The second most important application within the Federal Government is personnel information processing.[10] A work force which numbers several million persons dwarfs any company in industry and the immensity of the clerical task is evident. The third major use of computers in the Department of Defense is a general one and can be broadly defined as programming and planning. This includes such diverse functions as budgeting, critical path planning, and other such general non-logistic endeavors.[11] Research and Development uses are becoming more and more significant within the Department of Defense, also.

Within the Department of Defense the 1000 or more computers which are in use find vast applications in the programmed supply problems just mentioned. It may seem unfair

[9] Industrial College of the Armed Forces. Individual Report. Adaptability of Electronic Computers to Problems Affecting Economic Mobilization. Cdr. H. C. Goodwin USN, mimeographed. May, 1954: 34.

[10] _Ibid._: 36.

[11] _Ibid._: 36.

to describe supply problems as programmed, but [illegible]-vances in programming are considered, the reduction of stock-ing [illegible] to logical computer inputs is not difficult to project. While some years ago it was difficult to decide whether to send aircraft engines to various points and at what ranges and in what numbers to send them, now it is possible to evaluate on the basis of detailed and predict-able functions of the past usage, the optimum mixture of [illegible] points. This supply network is all-pervasive. A Navy [illegible] (to select one of the oldest military planes still flying) acting as embassy aircraft for the mission in Kara-chi, has a definite and efficient supply system for obtain-ing even the most complex parts.[12] Practically all supply problems, whether they deal with supplying an Antarctic force for six months or provisioning an entire submarine weapons system, are solved through the quantification of millions of items of information. Once this information is reduced to some coded form, the rules governing its use are put in force through a program dictated by user and supplier representatives. Without trying to minimize the complexity of this process, it does reduce to a structured predictable series of inputs, once the information has been developed. Of course, the computer aids in the development of the in-formation, too.

[12] Author's acquaintances with the Navy's Aviation Supply System.

Department of Defense Applications

The essence of the Department of Defense's approach to management is the use of quantified inputs to determine a range of possibilities and by various mathematical or empirical methods, development of a series of alternatives from which top management may choose. Especially during the last three years, there has been a significant increase in the Operations Research approach to Department of Defense problems.

There is a proliferation of definitions of Operations Research. The phrase Operations Research or Operations Analysis, Systems Analysis, and others which are similar, all connote an approach to a variety of problems. This approach involves reducing a process to a series of steps, noting the interactions of these steps and reducing all outputs and inputs to a representation often called a model. This model is tested with actual or simulated data and its suitability is determined by the relative accuracy with which it parallels the "real world" situation it represents. Finally, many techniques like linear programming seek to determine a "best" approach to a problem from the many approaches generated by the model. Linear programming and other tools like it are mathematical in nature and very easily lend themselves to computer based solutions.

The quantification methods described earlier concerning supply have been employed under the guidance of Mr. Charles J. Hitch, the Assistant Secretary of Defense, Comptroller, with the complete support of Secretary McNamara. A result

of this has been a consolidation of the decision making process within the Department of Defense. All decisions are now made on a total force concept, rather than Army, Navy, or Air Force.[13] The requests of the Air Force, for instance, for a wing of bombers, is considered not within the framework of the total Department of the Air Force budget, but rather within the total weapons arsenal available to the three services. If it is determined that the deterrent forces already available among the three services are adequate, the Air Force request is denied. The method for determining all this information is highly mechanized. Each service is required to draft a detailed analysis of the potential of its various constituents. As Mr. Hitch said,

> In the past, we have not always been as rigorous and analytical as we might have been.[14]

He admits that the selection of weapons systems, the design of forces, and the choice of the level of the national defense effort are "artistic", rather than scientific. Nevertheless, he believes that most situations can be quantified. This being the case, he demands that total systems costs, total potential hazards, and other such farsighted analyses of a total system be considered. While he concedes that it it impossible to compute a quantitative comparison, for

[13] Anonymous. Comptroller, Armed Forces Management, November, 1963: 64.

[14] Hitch, C. N. Operations Analysis in the Department of Defense. (from an address delivered at Duke University, Durham, N. C.) Bureau of Supplies and Accounts Newsletter, October, 1963: 16.

example, he decried the notion that such a flaw renders the system meaningless or valueless.[15] As mentioned earlier, in essence what the leadership of the Department of Defense requires is a set of alternatives. This is similar, indeed, to Step Two in the description of a decision process which was adopted previously. The separate services define the problem and also accomplish the second step of outlining alternatives. The Secretary of Defense is then able to make the third step more conclusively when he decides among these alternatives. To quote Mr. Hitch again,

> Our aim is to provide a climate in which the benefits of a quantitative analysis can be fully realized as an inherent part of the force design process. In this context our aim, rather than usurping such analyses, is to encourage them--to provide a form where they can be appreciated-- to assist however we can in expanding their use throughout the military organization.[16]

A different kind of military decision making process is the real-time command and control system. It is roughly similar to the process control systems in industry. Probably the most graphic example of these command and control systems is the SAGE System, which is a formidable on-line network of radar stations which automatically, through a computer switching system, gives early warning against bomber attacks. Through its many radar antennae it senses all

[15] Ibid.: 17. In a letter to the author, Mr. Hitch reiterated this view.

[16] Ibid.: 19.

aircraft entering the US air space. The sightings are automatically relayed over its telephone and microwave links to its central computers, which then can decide whether the encroaching planes are accounted for by flight plans on file, or whether they constitute a possible attack. If they do, it warns its human attendants, or can, under certain conditions, release the Bomarc interceptor rocket automatically.[17] Parenthetically, it might be mentioned that SAGE does not give warning against ballistic missiles.[18]

Among the Air Force's "L" systems, of which SAGE, or 416L, is the first, the NORAD joint service command and control system, the Strategic Air Command's intelligence system, SAC's command and control center in Omaha, and the BMEWS, the Ballistic Missile Early Warning System, are all examples of programmed decision making systems. Especially when the final decision to release an interceptor rocket is made within the program, all three of the decision steps discussed in Chapter III enter in under these systems. The Army and the Navy have similar command and control systems of varying magnitude,[19, 20] all of which

[17] Bergamini, D. Government by Computers? The Reporter, August 17, 1961: 25.

[18] Ibid.

[19] Hileman, R. The Navy Tactical Data System Modular Concept. Aerospace Engineering, April, 1962.

[20] Borklund, C. W. What's Ahead for Defense ADP? Armed Forces Management, July, 1961: 20.

are designed to process a maximum of information and generate a clear picture of the situation, hopefully in time for a decision by a human intermediary. The intermediary, however, is not a requirement in some of these systems.

There are many additional military examples in decision making by computer. The preponderance of computers in the supply and personnel fields should not suggest that all these problems have been reduced to a mechanized routine. A great number have been, but the accuracy of the machine and its speed have not decreased the need for decision rules. The need for these rules, especially in supply work, is accentuated by machine processing. In the past a representative of the General Accounting Office might be able to find fault with a particular set of human decisions as presented, say, on several stock cards. Since posting and processing stock cards have been among the first supply tasks to be computerized, the GAO representative no longer quarrels with the accuracy of individual postings. What he does analyze is the validity or adequacy of the decision making model, the stock control program. In many instances GAO has been severely critical of the "rules".[21] Of course, this does not condemn the use of computers in supply, but

[21] Comptroller General of the United States. Report to the Congress of the United States. Review of ADP used in Supply Management by the Department of the Navy, Aviation Supply Office, Philadelphia, Pa. Report Number B133118, mimeographed. 1962.

it accentuates the importance of decision rules, rules which a human must develop and test before assigning them as a computer's "policy".

Special Uses of Computers

In other government applications the computer has been suggested for a variety of specialized tasks. One of the most unusual proposals advanced appeared in the 1959 Proceedings of the Western Joint Computer Conference. Under the title, "Emergency Simulation of the Duties of the President of the United States",[22] the proposal was made that the President allow himself a rather extensive association period with a machine. This would give the machine a chance to "get used to" what the president's reactions are under varying situations. If the machine were programmed along these lines, the disability or incapacity of the president at a critical moment, would be a signal for activating this computer program, which would analyze all the information available regarding the situation and would act generally in accordance with what the president might have done, or so the writer suggests.

The author notes certain specific situations when this simulator might be used:

a. With congressional or popular consent upon learning of an emergency,

[22] Sutro, L. Emergency Simulation of the Duties of the President of the United States. 1959 Proceedings of the Western Joint Computer Conference: 314-323.

b. With a priori consent of the electorate well in advance of any critical situation.[23]

Another simulation is a system which was alleged to have been used with great success during the successful campaign which Mr. Kennedy waged for the Presidency in 1960.[24] A group of professors from Columbia University's Bureau of Applied Social Research conceived of a theory needed to build a computer model of the US television-viewing public. It is possible, this group determined, to develop a computer program which will predict the result of alternative campaign strategies from limited public opinion poll data (and to do so in a matter of minutes with great detail about different states and groups of voters). This simulator was alleged to be able to forecast reactions to religious issues, race issues, and many others which even the most ardent cyberneticists would think impossible. While the results of the model are not universally accepted throughout the scientific community, what this idea portends for government is rather interesting. If it were possible to assess the collective feelings of the electorate on a daily or even monthly basis, the Jeffersonian ideal of democracy would surely be attained. In fact, questions have been raised about the morality of using advanced computer programs in political research. As one writer noted, it seems ironical that people should view

[23] Ibid.: 322.

[24] Morgan, T. B. The People Machine. Harpers, January, 1961: 55.

decisions made on the basis of confused guesses about what the public wants as more democratic than decisions made on the basis of careful compilations of information.[25]

Whatever be the merits of the systems described above, they point to a possible use of computers for unstructured decisions. The ability of a computer to learn, in the general problem-solving sense developed by Simon, or the heuristic programming successes which have already been achieved in the playing of chess and other complicated games has been mentioned earlier. How far this progress might be extended is difficult to foresee. Nearly ten years ago, it was widely predicted that within a short time it would be possible to inject a Russian text into a machine translation program, and have as a result within minutes, a readable, usable English translation.[26] The results to this day have belied this prediction. Possibly, a threshold has been reached.

Before leaving this overview of the federal government's use of computers for decision making, it should be mentioned that many instances of complete failure or only marginal results are available within the government. Inadequate systems engineering has already resulted in several computer misfits, like the one at the Navy Supply Center in Norfolk.[27] The city of Seattle, to use a municipal example, discovered

[25] Ibid.: 57.

[26] Alt, Franz. op. cit.: 203.

[27] Bergamini. op. cit.: 27.

too late that a faulty program had caused the city's tax revenue to be over-estimated by 1.8 million dollars. Red faces all around did not solve the problem.[28]

When one considers the awesome dangers in the national situation today, the thought of a machine determining an active national policy is almost repugnant. Yet, more and more, the trend is toward developing special kinds of command and control machinery within the government much like the closed-loop processes described in industry. All these systems presuppose that it is feasible to program a system to act in nearly optimal fashion, and in any case, in a way which would not do a disservice to the nation. One sober fact about this supposition is that red faces like those of the Seattle planners would not alleviate the fearful consequences of a wrong decision within the command and control systems mentioned. All of this reduces to the desperate importance of correct programming and correct systems planning. It is doubtful if a second chance would be available to rectify a bad decision. One article described the feelings of an officer, who for obvious reasons was nameless, concerning the possible computerization of our war potential.[29]

> What is most frightening is that you've got the show being run by guys who have never been in a sandlot fight, never gotten a bloody nose. They're the ones setting up the battlefield for us.

[28] *Ibid*.

[29] Anonymous. Will "Computers" Run Wars of the Future? U. S. News and World Report, April 23, 1962: 48.

This criticism is certainly not held by all but it must represent one group's sentiments. Whether their argument has validity or not, the only time when an answer would be available would be during a crisis, and one hopes that the inputs to this vast, yet mechanical, decision making process are adequately programmed to ensure a decision favorable to our national aims.

A pattern which emerges seems to be the increasing computerization of all areas of the Federal Government. This also suggests that more and more of the structured decisions similar to those in industry will be made by machines. Nevertheless, the decisions cited fall roughly within the definition of <u>programmed decision</u> adopted in Chapter III. One gets the impression that there is great reluctance to allow a computer to perform tasks which Simon calls "non-programmed". (see Appendix II) Few of the citizenery would like to think of a heuristically programmed machine directing the destinies of our nation, ready to act with instantaneous and methodical precision to any of 10^x situations as X becomes larger with each new computer breakthrough. What the layman fears is that there may be more than 10^x situations possible or that one of these 10^x programmed solutions is not taking into consideration some ridiculously simple item in its determination.

CHAPTER VI

Miscellaneous Comments on Decision Making

The previous paragraphs have commented on the use of computers as decision makers. There is, however, a great deal of literature which reflects less than complete faith in this use of computers. First of all, there are many of the "negativists" who doubt the computer's ability to perform automatic cognition, relating cause and effect, the possession of judgment, and many other of the human attributes noted in Appendix IV. In an article published last year, "Computing ad Absurdum", Hilbert Schenk, Jr., decries the reliance which is placed on computers. He found it apt to cite a typical imaginary student who was so deeply enamored of a traffic pattern simulation that he lost all track of the actual traffic behaviour in his zeal for duplicating mathematically a particular unreal, but complicated model. Extending the young student's misplaced or erroneous effort to a more global problem, he asserts,

> Now I submit that the cool young men of Rand and a hundred other computing centers are in the same boat with my mythical student. For it is in the nature of thermonuclear war that no gaming model, whatever its sophistication, is amenable to even a shred of experimental proof. Much effort, for example, goes into simulations in which the resources of the United States are distributed around and about among several deterrents, like Polaris, Minuteman, shelters, etc. Simulated battles with Russia are played out inside the big machines with data in the form of casualties coming out at a rate of 600 lines a minute. All of it the purest baloney. As the machines get larger and the programmers more ingenious, the simulations become more intricate. Yet each new gene-

ration of simulated war builds on the previous ones, and none has any connection whatever with the most elementary considerations of scientific verification. 1

Obviously, then, there are detracters who would not acknowledge the survey results of the computer's use beyond clerical tasks.

Since a great number of the articles about computers and management are written by people either in academic or non-operating jobs, the author felt it would be worthwhile to seek out the opinions of the operators concerning the use of computers in management. To do this a questionnaire (see Appendix V) was devised which was designed to elicit comments from a selected group of 115 firms in the top 500 in the Fortune Magazine listing. The questionnaire was made up to avoid the simple dichotomous question. If the company interrogated desired to answer, it would be required to reply in some depth and it was felt that this would screen away many of the people who are accustomed to answering such questionnaires in a completely pro forma way. Of the 115 questionnaires sent out, 45 were returned. This is considered to be an unusually high rate for the type of questionnaire involved. Apparently, there were a great number of people who were piqued by the type of questionnaire, possibly because it affected their raison d'etre, in this case the computer division of the company.

1 Schenk, Jr., H. Computing ad Absurdum. Nation, June 15, 1963: 506.

In view of the very optimistic comments cited earlier, the answers to the questionnaire were a bit discouraging. At least half of those who returned the questionnaire admitted that management had substantial reservations about the use of computers. In order to give a flavor of the typical responses received, several of them will be quoted.

> 1. The idea that a computer can duplicate mental processes and make decisions is usually voiced by the machine salesman or someone who is acquainted with computers from a theoretical standpoint only...we feel that the computer has a definite work (sic) for our company and that it pays its way both as a labor saving device and as a means of furnishing statistical data... we do not anticipate the computer supplanting policy-making management, nor does it appear that human judgment can be entirely replaced all down the line of decision making. [2]

The data-processing manager for one of the largest automobile manufacturers in the world comments,

> 2. We speak of major new concepts and major new data-processing tools, but somehow our daily business lives aren't as radically different as we thought or hoped they might be back in 1958...for those of us in business systems work the systems concepts don't go very far beyond those of some years ago and only the equipment used is different. [3]

[2] Lt. S. R. Ruth Files. Letter Number 55.

[3] Neese, A. Systems for Management Control. Address. Included as part of reply. Number 169 in Ruth Files.

The idea of the computer is extremely well accepted by management and its use is actively encouraged... in many cases the computer decision is subject to final review by people. 4

There are no general reservations on the part of management as to the use of computers other than that the use must be economically justified. As in all areas of change, there does exist some inertia on the part of the functional organizations. This inertia must be overcome by a demonstration of the feasibility of computerizing their function. 5

Computers are being assigned more and more of the decision making for the relatively routine decisions for which decision rules are simple to define, but where the number of variables to consider are large, stock control and distribution are typical examples. 6

We have no computers which decide anything. True, we might ask a computer to write a purchase order when needed, but only under circumstances where we are content to say, in advance, that the same order for the same quantity for the same price shall be sent to the same vendor whenever the stock on hand is found to be below the minimum. This is decision implementation, is it not?.... As far as we know, computers have practically no capacity to make decisions on their own. 7

The computer never decides anything and we consciously avoid giving this impression....management is suspicious of decisions by data processing or management by machine. 8

There has been a definite trend within our organization to let computers try to do more and more. However, this has been motivated by the desire to save clerical expense, to increase the efficiency of record keeping, than by the desire to limit the number of decision makers in higher management. I know of no

[4] Ruth Files. Letter Number 125.

[5] Ruth Files. Letter Number 41.

[6] Ibid.

[7] Ruth Files. Letter Number 25.

[8] Ruth Files. Letter Number 127.

> instance where computers have actually taken over the decision making function. [9]
>
> Decisions are made by people. The destiny of a computer....is primarily performance of clerical tasks. [10]

This from a brewery:

> On the whole there are some 15% more managerial positions now in our corporation than there were five years ago. This is due in part to the computer orientation of the company. [11]

This from a computer manufacturing concern:

> Despite our deep involvement in computers, it would not be correct to say that the computer's use is pervasive...there are certain top-management reservations--and I carefully distinguish between top management and what you refer to as the management level. The use of a computer in decision making implies the ability to use a rather rigorous approach to the problem-solving process. Oddly, the very business we are in is not yet sufficiently mature to permit a degree of rigor, indeed desirable, to be applied...we believe it will be some time before the computer will impact the number of decision makers in management. We feel that the computer is destined to assist in highly sophisticated decision making, but the state of the art at this point is certainly not such that this will find more than occasional acceptance. As a matter of fact, to some extent we may have a "shoemaker mend your shoes" situation. [12]

Unquestionably, the preponderance of replies which reflected the cautious or even suspicious attitude about machine decision making beyond the clerical levels belies the idea that computers can soon "take over". Since most

[9] Ruth Files. Letter Number 13.

[10] Ruth Files. Letter Number 127.

[11] Ruth Files. Letter Number 27.

[12] Ruth Files. Letter Number 113.

of the people who answered the letters were at the top management level, e. g., comptroller, directors of data systems, etc., their answers probably reflected company policy as adequately as any could. Very possibly these opinions reflect, even more than published articles or pronouncements to stock holders, the real feelings of management toward computers. Whether or not these comments have validity, they do lend a certain real-world flavor to the subject under discussion.

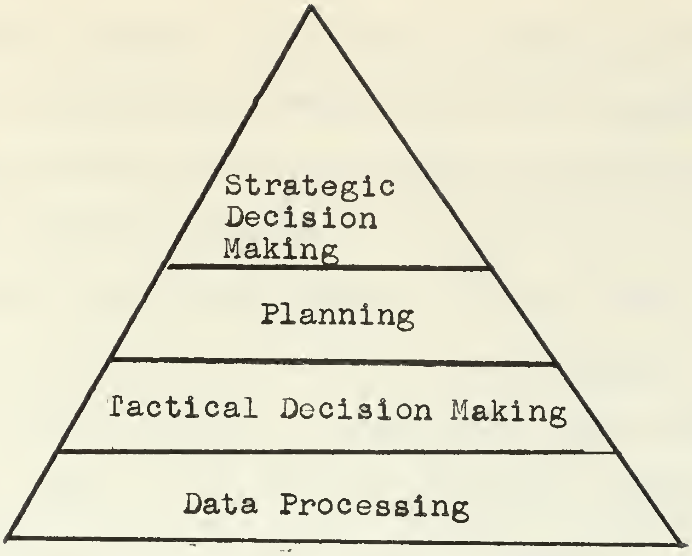
CHAPTER VII

DISCUSSION AND SUMMARY

Now that a broad base has been developed for considering the status of the computer as a decision maker, several general ideas have developed. First of all, there is obviously already considerable sophistication in such control problems as automating a chemical process by automatic measurement of the characteristics of the entering raw materials, the chemical that is produced, and the temperature, pressure, and other physical parameters. This on-line use of the computer as a decision maker is paralleled by the operation of many of the military decision systems cited previously. If these were typical of the entire spectrum of decision making situations in government and in industry, we could certainly expect an entirely computer-dominated structure in both very soon. What actually seems to be the case is a hierarchy of decision making. One author has compared this hierarchy to a triangle, which is pictured below.[1]

The top two segments of the triangle, strategic decision making and planning, are the areas in which direct computer applications have been more limited. What has been emphasized by all the computer users in industry and

[1] Haskins, M. Trends in Computer Applications. Data Processing for Automation, January, 1963: 40.



in government is the importance of the human's assistance in decision making. This intervention is particularly noticeable in the strategic decision making and planning areas. (Planning here, as in Chapter IV, refers to actually conceiving or devising the plan. Once the plan has been established, many computerized methods like PERT[2] and others find useful application.) Granted, great quantities of data are made available to the persons responsible for the decisions, but the decisions themselves are typically made after an analysis of this information rather than by a machine which operates probabilistically or in any other empirical way on data supplied it.

The two lower trapezoids in the picture emerge as the areas already developed with increasing effect and range

[2] CDC, Pert Manual for Operations. CDC Computer Division. No date.

by all computer users. The Tactical decision making, as used in the illustration, ranges from the programmed stock replenishment decision to the feedback generated in an on-line fuel cracking plant, to the selection of targets of importance in the SAGE System. It is in this range particularly, where great progress in management and decision making has occurred. Apparently, then, this great progress has been in the form of providing managers with better information for them to use in making the decisions, or, in the sense of the simpler decisions, with supplying enough information to a well programmed system to allow it to develop correct answers to predictable questions very rapidly.

As to whether machine applications duplicate or parallel the human decision process, the point has been stressed that some very obvious similarities do exist. Yet, the electronic data processing machine arrives at decisions in a logical manner, and makes only one at a time. Unlike the human mind, it does not have the ability to compress a long sequence into what appears to be a single jump.[3]

Some have suggested that a machine can make decisions but it cannot exercise judgment. Many types of decisions of this sort have been noted. The ability of heuristic

[3] United States Navy, Bureau of Supplies and Accounts. Introduction to Electronic Data Processing Machine Applications. Nav S and A Publication 283, 10 March 1955: 10-3.

programs to incorporate in their processes one or more aspects of what might be called "the art of plausible reasoning" suggests that this judgment function might become one of the numerous diverse ill-structured decisions which machines, properly programmed, could make. (For an example, see Appendix IV, A6-A9) As Simon states:

> The fact that chess programs, theorem proving programs, music composing programs, and a factory scheduling program now exist, indicates that the conceptual mountains that barred us from understanding how the human mind grapples with everyday affairs have been crossed. [4]

The degree to which heuristics can be made to correspond to the skill a businessman uses when he makes a decision becomes an important point of discussion. Several authors have pointed out that if we succeed in devising a program that simulates the subject's behavior rather closely over a significant range of problem solving situations, then we can regard the program as a theory of the behavior. How highly we will prize the theory depends, as with all theories, on its generality and parsimony--how wide a range of phenomena it explains and how economical an expression it is.[5]

If the work of Simon and Newell, Goodwin, Hiller and Isaacson, et al, is to have meaning, it must certainly be

[4] Simon, H. Management By Machine; How Much and How Soon. The Management Review, November, 1960: 74.

[5] Synthesis of author's reading in this aspect of the subject.

that sophisticated programming holds promise for making unstructured decisions, whether they be decisions arrived at by learning, or by innovation. In fact, a good case has been made for the ability to program a computer to innovate.[6]

The value of operations research as a tool for optimizing certain parts of a process was mentioned. It, like practically all other decision making tools previously discussed, depends upon the inherent ability of people to reduce the structure of a process to numbers. The more representative the system of numbers, the more reasonable will be the decisions arrived at using the model. Again, Appendix IV shows in clear terms the type of human operations which can be compared to machine operations. One might infer from this chart that the final level, "commands others", is one which will logically and inexorably follow from a machine's mastery of the previous levels. This sort of reasoning is deceptive.

Finally, a subtle but highly significant benefit of the computer's use in the decision making process must be mentioned. Whenever a computer is introduced into a decision process, what occurs invariably is a detailed, functional, task-by-task analysis. Aside from the obvious intended savings through computer oriented techniques, the very definition of the problem in such a detailed way often

[6] Kugel, P. The Computer in the Bathtub. Computers and Automation, August, 1963: 12ff.

reveals weaknesses never before noted in cursory management studies. This "side effect" is possibly as important as any other benefit derived from computers.

CHAPTER VIII

CONCLUSIONS

The following conclusions, based on the material presented previously, are considered significant.

1. The trend in both government and industry is toward increased utilization of computer-based decision systems.

2. These decision systems are typically on the level of the repetitive, structured decisions which make up a large percentage of the total tasks.

3. In general, the concepts of heuristic programming and learning machines have not found substantial application in business or government applications. However, there is reason to expect that these applications may eventually replace some current "non-programmed" systems.

4. An important aid which computers have given the manager has been new insight into problem and system definition. The nature of the information required demands a thorough appraisal of the entire flow of activity in an organization. This has resulted in efficiency, not only in the resulting program, but in the redefinition of the purpose of the organization.

5. There is a substantial element among top management in industry which is skeptical about the computer in the decision process. This skepticism is manifested by lack of support for some computerized activities and a lack of interest in several important aspects of computer potential in industry.

6. The Turing school, which holds that computers are capable of practically any achievement humans are, (given proper capacity and "education") is not popular among the "operating people". That is, the theoreticians tend to be "positivists", while the people actually making the decisions seem to be "negativists".

7. The advent of a Total Management System like that developed by Westinghouse accentuates the computer's ability to process, compute, correlate and report. This system is valuable because it presents the ultimate decision maker, the manager, with more information--not because it <u>of itself</u> makes decisions.

As many writers are beginning to concede, the computer's greatest benefit may be as an "intelligence amplifier". The idea of the brain's richness being enhanced by the relentless accuracy of a computing machine places the marvel of the computer's achievement in a more reasonable light. As Dr. Ramo[1] concluded:

> It is not man's muscles that are to be replaced and extended but rather man's brains....and anyone who is foolhardy enough to challenge the idea that the replacing of man's brains will be the top industry in the nation some years hence is in danger of having his brains among the first to be replaced.

[1] Ramo, S. Automation in Business and Industry, Eugene M. Grabbe, editor, John Wiley and Sons, Inc., 1957: 9.

Acknowledgement

The author deeply appreciates the help of Professor D. G. Williams, whose continuing guidance and interest have contributed significantly to the completion of this thesis.

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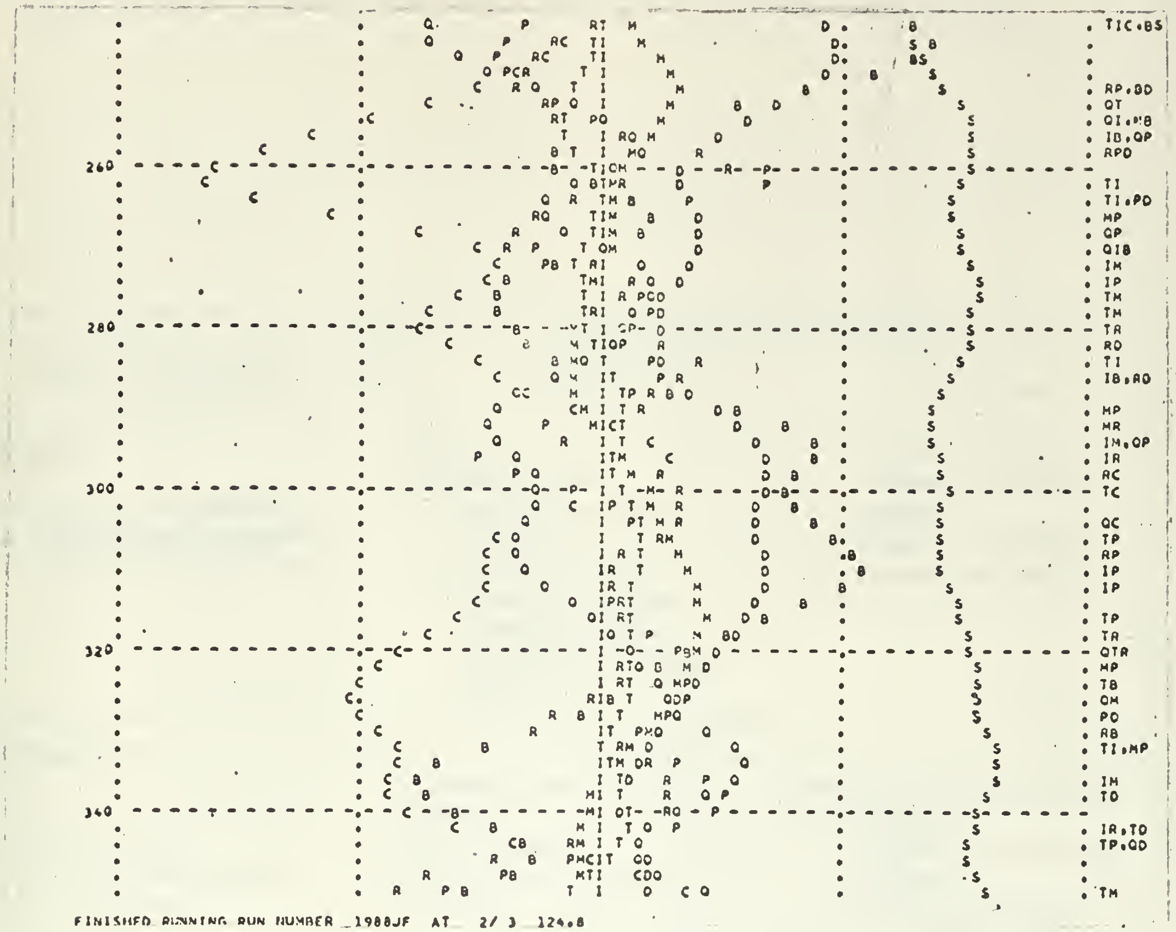
APPENDIX I

COMPUTER OUTPUT FOR TYPICAL INDUSTRIAL DYNAMICS PROBLEM



Key: Letters represent points on a graph for various parameters of the electronic component industry. S is percent of orders filled from inventory; B- total factory backlog; I- constant input; D- delivery delay,etc. Ordinate represents time units. Abscissa is variously : percent,orders filled, and delivery delay in weeks. Forrester,J. Industrial Dynamics. The MIT Press, 1961, p. 381.

APPENDIX II

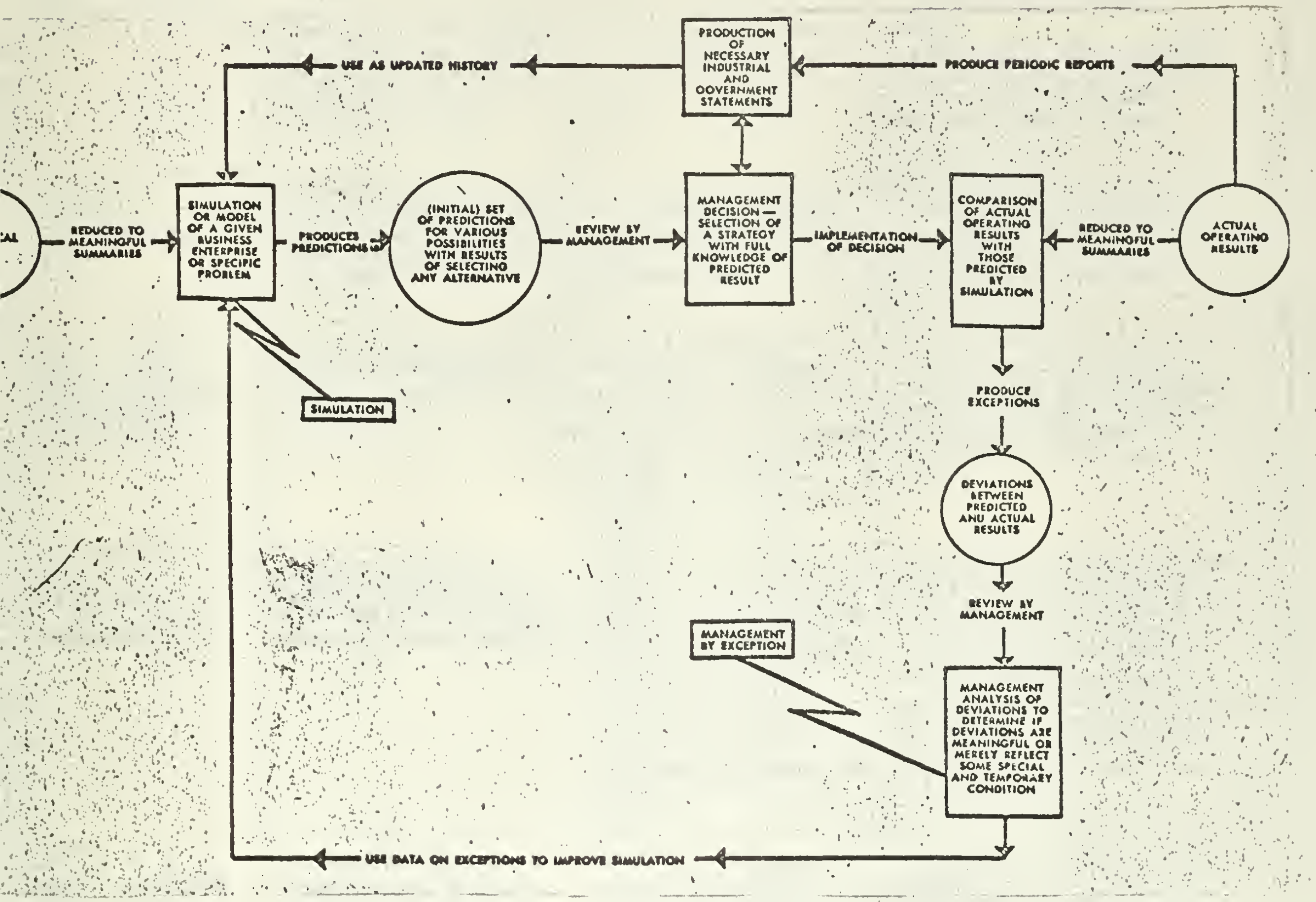
COMPARISON IN DETAIL OF SIMON'S DECISION HIERARCHY*

TYPES OF DECISIONS	DECISION-MAKING TECHNIQUES *Traditional*	 *Modern*
Programmed: Routine, repetitive decisions Organization develops specific processes for handling them	1. Habit 2. Clerical routine: Standard operating procedures 3. Organization structure: Common expectations A system of subgoals Well-defined informational channels	1. Operations Research: Mathematical analysis Models Computer simulation 2. Electronic data processing
Nonprogrammed: One-shot, ill-structured novel, policy decisions Handled by general problem-solving processes	1. Judgment, intuition, and creativity 2. Rules of thumb 3. Selection and training of executives	Heuristic problem-solving techniques applied to: (a) training human decision makers (b) constructing heuristic computer programs

* Simon, H., The New Science of Management Decision. Harper and Row, 1960: p 8.

APPENDIX III

SCHEMATIC OF MARTINO'S TOTAL MANAGEMENT SYSTEM



Martino, R.L. A Total Management System. Datamation. April 1963, p. 32.

APPENDIX IV

AMBER'S HIERARCHY OF AUTOMATICITY *

ORDER OF AUTOMATICITY	HUMAN ATTRIBUTE MECHANIZED	DISCUSSION	EXAMPLES
A_0 HAND TOOLS AND MANUAL MACHINES	NONE—Without self-action properties. Does not replace human energy or basic control but may include built-in guides and measurements. Includes all hand tools. They increase workers efficiency but do not replace human function.	Includes all muscle energized machines. They give mechanical advantages but do not replace man's energy or control. Simple machines are: lever, inclined plane, wheel and axle, screw, pulley, and wedge.	Shovel, knife, pliers, axe, crowbar, hammer, scissors, wrench, file, handsaw, bellows, paintbrush, trowel. Block and tackle, pencil sharpener, bow and arrow, bicycle, typewriter churn, wheelbarrow, tirepump, desk stapler, jack, hand lawnmower, handloom.
A_1 POWERED MACHINES AND TOOLS	ENERGY—Muscles are replaced for the basic machine function. Machine action and control completely dependent upon operator.	Uses mechanical power (windmill, waterwheel, steam engine, electric motor) but man positions work and machine for desired action.	Snag grinder, cement troweling machine, portable floor polisher, electric hand drill, drillpress, air hammer, power lawnmower, spray gun, belt sander, electric (or spring wound) shaver.
A_2 SINGLE-CYCLE AUTOMATICS AND SELF-FEEDING MACHINES	DEXTERITY—Completes an action when initiated by an operator. Feeds tool to the work by power.	Includes all single cycle automatic machines. Operator must set up, load, initiate actions, adjust, and unload. However A_3, A_4, or A_5 control systems may be superimposed on basically A_2 machines to reduce the dependence on operator skills.	Pipe threading machine, radial drill, electro-erosion machine, precision boring machine (without accessory automatic control system), machine tools, such as grinder, planer, mill, shaper, lathe.
A_3 AUTOMATIC; REPEATS CYCLE	DILIGENCE—Carries out routine instructions without aid by man. Starts cycles and repeats actions automatically.	Includes all automatic machines. Loads, goes through a sequence of operations, unloads to next station or machine. Open loop (not self-correcting) performance. Obeys internal (fixed) or external (variable) program, such as cams, tapes, or cards. Includes transfer machines and "Detroit" automation.	Engine production lines; self-feed press lines; automatic copying lathe; automatic gear hobbers; automatic assembly of switches, TV's, relays, locks, valves; machines for making springs, bottles, hinges, chain, cartons, doughnuts; automatic packaging. Also record-playback and numerical programmed machines which are not self-correcting.
A_4 SELF MEASURING AND ADJUSTING; FEEDBACK	JUDGEMENT—Measures and compares result to the desired size or position and adjusts to minimize any error.	Although feedback control of the actual surface of the workpiece is preferable, positional control of the machine table or tool is of great value too. A process may use more than one A_4 subsystem operating independently.	Feedback from <u>product</u>: automatic sizing grinders; size-controlled honing machines, dynamic balancing; color matching or blending; level control; weight control; chemical milling; process controllers. <u>Positional</u> feedback: pattern tracing flame cutter; servo-assisted follower control; feedback control of machine tool table, saddle, and spindle; tape controlled machines (only if self-correcting).
A_5 COMPUTER CONTROL; AUTOMATIC COGNITION	EVALUATION—Is cognizant of multiple factors on which machine or process performance is predicated, evaluates and reconciles them by means of computer operations to determine proper control action.	Any process or problem which can be expressed as an equation can be computer controlled. This includes <u>automatic cognition</u>, the awareness of variations in materials, in process conditions, and in the work. Monitors are simple limited purpose computers used to accomplish A_5 computer control.	Rate-of-feed cutting; machinability control; maintaining pH; error compensation; turbine fuel control; dynamic positioning; selective assembly; self-optimizing (maxima-minima); Auto-QC calculations; interpolation between data points.

* Amber, G., and Amber, P., Anatomy of Automation. McGraw-Hill. 1957 p.2-3.

ORDER OF AUTOMATICITY	HUMAN ATTRIBUTE MECHANIZED	DISCUSSION	EXAMPLES
A_6 LIMITED SELF-PROGRAMMING	LEARNING—Machine sets up and tries subroutines, based on the general program. By remembering which actions were most effective in obtaining the desired results, the machine "learns by experience."	The subroutines are a form of limited self-programming. This may be preferable to providing the necessary memory storage and recall apparatus for complete programming in a complex computer.	Utilization of intercity telephone circuits, sophisticated elevator dispatching; "mock tortoise"; mechanical "maze running rat," neurological models, "telelogical" machine.
A_7 RELATES CAUSE FROM EFFECTS	REASONING—Ability to forecast trends, patterns and relationships, from incomplete facts. Exhibits "intuition" by going beyond available data.	Theory of Games, Monte Carlo method, and other strategies may be the basis of operation. Inductive reasoning A_7 is not the same as deductive reasoning A_5; analysis requires deduction. Synthesis requires induction.	Sales prediction, weather forecasting, "champion" chessplayer, automatic OR, population patterns, lamp failure anticipation, actuaria analysis.
A_8 ORIGINALITY	CREATIVENESS—The ability to originate works to suit human tastes and preferences. Not copying, imitating, or following plans and instructions.	The program only designates the general form of the desired action and eliminates clashes, discords, and disharmonies. The actual result is original.	Write music; design fabric patterns; formulate new drugs and chemicals; write poetry? design products? create paintings? create original automatic machines?
A_9 COMMANDS OTHERS	DOMINANCE—Governs actions of men, machines, and other systems. Acts as a "commanding general" or as a "dictator" to achieve results. Machine is no longer servant but master.	An A_9 supermachine capable of superior energy (A_1), dexterity (A_2), diligence (A_3), judgement (A_4), evaluation (A_5), learning (A_6), reasoning (A_7), and creativeness (A_8), would be able to dominate man.	The authors decline to cite examples of A_9 automation. Science-fiction writers are talented in conjecturing such machines, so examples of higher orders of automaticity are best left to their imaginations.

U. S. NAVAL POSTGRADUATE SCHOOL
Monterey, California

APPENDIX V

QUESTIONNAIRE

December 12, 1963
Box 1948 USNPGS
Monterey, California

Dear Sir:

As an officer student in the Computer Science curriculum here at the U.S. Naval Postgraduate School, I am now engaged in research for my Masters thesis. The general theme is, The Computer's Place In The Decision Making Process. This is a very broad-sounding subject. However, I plan to restrict myself to the actual decision making at crucial points in the corporate or industrial cycle as opposed to the obvious lesser decisions which computers can make in such increasingly minuscule time frames. One article in a business publication a few months ago quoted an officer of a leading company as stating that after the computer had done the work all that was needed was "a dash of judgment." By contrast, an article published this spring stated that only a third of the companies consulted in a survey had been able to get their computers to pay for themselves. All this, combined with the comments of Doctor Weiner that the human thought processes can be duplicated in a computer in such combinations as to outstrip the human's mental resources, suggests that one of the best ways to arrive at any clear idea, is to ask the groups who are actually working with these machines. This is my purpose in writing this letter.

Specifically I would very much appreciate some or all of the information requested in the enclosed questionnaire. If my questions very nearly coincide with certain pamphlets or "handouts" already available through normal channels I would appreciate your forwarding them to me. If it would be possible to have copies of any data which is germane to these topics given me on a very temporary basis, I assure you the information will be returned on time.

The enclosed questionnaire is meant to be quite general. My hope is that one or more of the questions might be particularly appropriate for your company. Once again, what I'm really looking for is comments from those who really know - the users and the managers. I will also be contacting a number of government installations seeking much the same sort of information.

Anything you can send would be very much appreciated. In case there is any information which is of interest but which you do not desire me to use under your name in the thesis, I would of course comply with any such restrictions.

Sincerely,

Stephen R. Ruth

Stephen R. Ruth
LT, SC USN

The following questions are meant to be quite general in nature and any comments appropriate to your company's operations which are directly or indirectly applicable would be helpful.

The word "computer" as used here refers to the machine itself along with all the associated unit record and other such equipment which is related to your specific operations.

Question "A" — Are there any general comments which would characterize your company's approach to computer operations; for example, is the computer's use completely pervasive or are there still certain general reservations at the management level?

Question "B" — Has there been a trend to let the computer try to do more and more, thereby limiting the number of decision makers in higher management or has there been some noticeable leveling off of the number of situations when the machine actually "decides?"

Question "C" — Does the computer seem destined to be able to perform highly sophisticated decision making or do you feel that its proper place is in the more clerical tasks?

Question "D" — Is there any available resume of your firm's association with computers, which would illustrate the changes in management configuration and especially the changes in actual types of decision making (man vs. machine) before and after computers?

Question "E" — Has your experience resulted in any rules of thumb or general limitations concerning the use of computers as decision makers?

Question "F" — Is there any other material available from your company in the form of pamphlets, brochures, company "newsletter," etc., which would be appropriate to questions "A" - "F"?